# Closeout Report on the DOE/SC CD-2/3 Review of the

# Muon g–2 Project

## Fermi National Accelerator Laboratory

**July 29-31, 2014**

**Kurt W. Fisher**
**Committee Chair**
**Office of Science, U.S. Department of Energy**
http://www.science.doe.gov/opa/

# Review Committee Participants

U.S. DEPARTMENT OF ENERGY — OFFICE OF SCIENCE

## Kurt W. Fisher, DOE/SC, Chairperson

**SC1**
**Accelerator**

* Rod Gerig
Peter Ostroumov, ANL

**SC2**
**Storage Ring**

* Soren Prestemon, LBNL
Sasha Zholents, ANL
Mike Zisman, LBNL

**SC3**
**Technical Integration**

* Marc Ross, SLAC
Claus Rode, TJNAF
Bruce Strauss, DOE/SC

**SC4**
**Instrumentation**

* Bill Wisniewski, SLAC
Richard Kass, OSU
Walter Toki, Colorado State
Ren-yuan Zhu, Caltech

**SC5**
**Cost and Schedule**

* Ron Lutha, DOE/ASO
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**SC6**
**Project Management and ES&H**

* Dan Green, FNAL Emeritus
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Steve Trotter, ORNL

**Observers**

Mike Procario, DOE/SC
Alan Stone, DOE/SC
Ted Lavine, DOE/SC
Tim Bolton, DOE/SC
Pepin Carolan, DOE/FSO
Paul Philp, DOE/FSO

**LEGEND**

SC Subcommittee
* Chairperson

**Count: 18 (excluding observers)**

# Charge Questions

1. Do the proposed technical design and associated implementation approach satisfy the performance requirements? How has the project team ensured that the subsystems will be fully integrated? Are the CD-4 goals reasonable and well defined?

2. Is the cost estimate and schedule consistent with the plan to deliver the technical scope? Is the contingency adequate for the risk?

3. Is the management structure and resources adequate to deliver the proposed technical scope within the baseline budget and schedule as specified in the PEP?

4. Is the documentation required by DOE Order 413.3B for CD-2 complete?

5. Are ES&H aspects being properly addressed given the project's current stage of development?

6. Has the project responded satisfactorily to the recommendations from the previous independent project review?

7. Is the detailed design sufficiently mature so that the project can commence procurement and fabrication? Are the current project cost and schedule projections consistent with the baseline cost and schedule in the PEP? Is the contingency adequate for risks?

8. Is the documentation required by DOE Order 413.3B for CD-3 complete?

# 2.1 Accelerator

R. Gerig, P. Ostroumov / Subcommittee 1



1. Do the proposed technical design and associated implementation approach satisfy the performance requirements? How has the project team ensured that the subsystems will be fully integrated? Are the CD-4 goals reasonable and well defined? We suggest that the threshold KPPs be strengthened. See comments.

3. Is the management structure and resources adequate to deliver the proposed technical scope within the baseline budget and schedule as specified in the PEP? Yes

4. Is the documentation required by DOE Order 413.3B for CD-2 complete? Interface requirements should be captured as CD-2 documents.

6. Has the project responded satisfactorily to the recommendations from the previous independent project review? Yes to IPR; Director's review recommendations are recent. We concur with the Accelerator recommendations from the Director's review, and reemphasize them in our report.

7. Is the detailed design sufficiently mature so that the project can commence procurement and fabrication? Yes, pending the outcome of beam dynamics review. Are the current project cost and schedule projections consistent with the baseline cost and schedule in the PEP? Yes. Is the contingency adequate for risks? Yes

8. Is the documentation required by DOE Order 413.3B for CD-3 complete? Yes

## Findings

- There has been significant good work completed since the CD-1 review resulting in simpler designs and cost savings. An example is the merging of the M2/M3 lines.

- The accelerator scope of work (476.2) is the largest “Level 2” cost at $18M.

- The critical path for the project runs through accelerator systems. According to the project, this activity is delayed due to accessibility to tunnel areas that are only available during accelerator shutdowns; and to the way the funding profile is constructed. There is zero float to the early completion date, but two years float to CD-4.

- The L3 managers expressed concern regarding obtaining Fermilab labor when needed.

## Findings

- Transport of low-intensity secondary beams requires a set of unique beam instrumentation. The project team is developing ion chambers for the beam intensity measurements and secondary emission monitors (SEM) and proportional wire chambers (PWC) for the measurement of beam center and profile.

## Comments

- There are significant beam dynamics issues that are addressed in this WBS, from the final focus on the target, to injection into the ring. Good design work has been done, but there has not been an independent technical, accelerator physics, review of the design. The committee feels that this should be done before CD-2.

- There remains a lack of rigor in the definition of the interface between the storage ring beam dynamics requirements and the accelerator beamline design. We suggest that this be provided by the storage ring group, before the above review.

- The project has established two levels of KPPs: "Threshold" and "Objective". Threshold KPPs assume that there are significant constraints outside of the project's control (e.g., accelerator shutdown availability, and the completion of AIP, GPP projects). We believe that these issues can be significantly mitigated allowing the Threshold KPPs to be rewritten much closer to the objective KPPs, and encourage the project to consider this.

## Comments

- The accelerator team is attempting to address scheduling issues by minimizing the need for accelerator shutdowns to complete work in the M3 area. We encourage this effort.
- A review of the BOE of several accelerator systems revealed a thorough understanding of the costs and effort required.
- There are notable spikes in effort profiles in this area as well as others. It is difficult for this committee to assess the real impact on resource requirements without seeing the bigger picture of all Fermilab projects. We note this as a concern.
- There has been significant, successful, reliability testing of the lithium lens and power supply at 12 Hz, but this testing did not incorporate the burst mode which g-2 will use. We encourage the project to test all pulsed power supplies in 100 Hz burst mode at ~12 Hz as soon as possible.

## Comments

- There are considerable g-2 dependencies on Fermilab resources outside of the project. We encourage the project to write MOUs as appropriate to ensure on-schedule delivery. A particular example is magnet construction by TD.

- Of three new types of beam diagnostics devices for secondary particles, only the ion chamber has been tested with low-intensity beams. The list of milestones does not show any beam testing for Secondary Emission Monitors (SEMs) and Proportional Wire Chambers (PWCs) until the secondary beams are available at the end of this Project. There is a significant concern about the performance of SEMs at low beam intensities down to $10^7$ particles/bunch. PWCs are designed to monitor beams at $10^5$ particles/bunch level. Early testing of SEMs and PWCs with low intensity beams is encouraged.

## Recommendations

1. Perform an independent technical review of the beamline accelerator physics design from the final focus on the target to the injection into the storage ring. Incorporate any changes from this review into the conceptual/technical design report before CD-2.

# 2.2 Storage Ring

S. Prestemon, M. Zisman, LBNL
A. Zholents, ANL / Subcommittee 2



1. Do the proposed technical design and associated implementation approach satisfy the performance requirements? How has the project team ensured that the subsystems will be fully integrated? Are the CD-4 goals reasonable and well defined? Yes. The integration should be strengthened as the project proceeds. Consider strengthening KPPs (see comments).
2. Is the management structure and resources adequate to deliver the proposed technical scope within the baseline budget and schedule as specified in the PEP? Yes.
3. Is the documentation required by DOE Order 413.3B for CD-2 complete?
4. Has the project responded satisfactorily to the recommendations from the previous independent project review?
5. Is the detailed design sufficiently mature so that the project can commence procurement and fabrication? Are the current project cost and schedule projections consistent with the baseline cost and schedule in the PEP? Is the contingency adequate for risks? The design is ready for the project to proceed with essential procurements and preparations for magnet cooldown.
6. Is the documentation required by DOE Order 413.3B for CD-3 complete? No, the design is not fully fleshed out.

# 2.2 Storage Ring

S. Prestemon, M. Zisman, LBNL
A. Zholents, ANL / Subcommittee 2

- **Findings:**
  - The BNL ring has been delivered to FNAL and is ready for installation in the MC-1building.
  - In the building!
  - The project team is fully established and functioning well.
  - The project is highly inter-dependent on GPP and AIP efforts.
  - Project management tools, *e.g.* change control, scheduling, BOE, etc are all in place.
  - The ring WBS has 34% contingency, highest among the top WBS elements.
  - Ring costs are roughly evenly split between labor and M&S.
  - The CD4 date has 2 years contingency.
  - The baseline is to re-use the existing inflector. The first one was partially disassembled; in principle it could be rebuilt. The inflector is not on the critical path, but it is not far off.
  - Systematic errors are now likely to dominate the measurement accuracy.
  - Implementing a new inflector design would
    - Potentially result in an increase in flux by a factor of 2-3;
    - Allow $mu^-$ as well as $mu^+$, i.e. access new physics.
  - The inflector can be replaced in about 1 month.
  - The electrostatic quadrupoles utilize the same switching system as at BNL (but refurbished).
  - Standard FNAL software solutions are being applied to the instrumentation and controls.

# 2.2 Storage Ring

S. Prestemon, M. Zisman, LBNL
A. Zholents, ANL / Subcommittee 2

- **Comments:**
  - Consider strengthening the KPPs, for example moving some of the “Objective KPPs” to “Threshold KPPs”.
  - Developing the improved inflector mitigates project risk (both for science deliverable and for hardware risk associated with failure of the existing inflector), and may improve physics reach. Management should work hard to support the development.
  - Consider benefits of optimizing the M5 beamline based on the energy and betatron acceptances of the ring.
  - It is important to optimize vacuum quality near the electrostatic quads:
    - Verify experimentally that the anticipated vacuum quality of $10^{-6}$ will be sufficient for operation of the electrostatic quads, especially at 75kV if needed;
  - The magnet cryostat should be reviewed from an FNAL safety perspective.

# 2.2 Storage Ring

S. Prestemon, M. Zisman, LBNL
A. Zholents, ANL / Subcommittee 2



- **Comments:**
  - The project should provide concise documentation to support decision making:
    - Identification and rationale for baseline choices for each component (e.g. Q1).
    - The cost-benefit analysis of refurbishment vs procurement for the main ring power supply and critical pulsed power supplies;
    - Make/buy decisions on components, e.g., resistive magnets;
    - Required interlocks and their cost and schedule;
    - Table(s) that show all components required for science operations, and their responsible parties (e.g. project, AIP, or GPP);
    - The optimization and tradeoffs associated with the kicker design, e.g., look at benefits of more, shorter, kickers (e.g. 4 vs 3), which would reduce rise time and may provide operational risk reduction;
    - Requirements and possible feedback approaches to minimize systematic errors associated with the E-field interaction, applied for example to the beam profile and the injection beam orbit stability.
    - Uncertainties in the anticipated systematic errors, the resulting science impacts, and contingency plans to improve the systematics (e.g. temperature gradients).

- **Recommendations:**
  - Continue to develop a preliminary design of a new inflector and associated beam optics/detectors to maximize muon delivery to the ring.
    - Perform a detailed comparison of capture efficiency with the existing and the improved inflector designs (including any required beamline optics changes) to quantify potential improvements. (See recommendation for a Technical Review in the Accelerator section).
  - Develop a requirements document on what the beam line delivers, how it is controlled, and the flexibility of delivery characteristics . (See recommendation for a Technical Review in the Accelerator section).
  - Develop appropriate test plans and acceptance criteria for each refurbished and new component (e.g. Kicker).

# 2.3 Technical Integration

M. Ross, SLAC*, B. Strauss, DOE/SC
C. Rode, TJNAF / SC-3



1) Do the proposed technical design and associated implementation approach satisfy the performance requirements? How has the project ensured that the subsystems will be fully integrated? Are the CD-4 goals reasonable and well defined?

***Yes.***

3) Is the management structure and resources adequate to deliver the proposed technical scope with the baseline budget and schedule as specified in the PEP?

***Yes.***

4) Is the documentation required by DOE Order 413.3B for CD-2 complete?

***See below.***

6) Has the project responded satisfactorily to the recommendations from the previous independent project review?

***Yes.***

7) Is the detailed design sufficiently mature so that the project can commence procurement and fabrication? Are the current project cost and schedule projections consistent with the baseline cost and schedule in the PEP? Is the contingency adequate for risks?

***See below.***

8) Is the documentation required by DOE Order 413.3B for CD-3 complete?

***Yes.***

# 2.3 Technical Integration

M. Ross, SLAC*, B. Strauss, DOE/SC
C. Rode, TJNAF / SC-3

- **Off-Project Work - Findings:**

  - **The successful of the Muon g-2 Experiment relies on the realization of seven off-project Accelerator Improvement Projects (AIP) and General Plant Projects. The AIP's (with the exception of the almost-completed Cryogenics System AIP) are 10 to 20% complete. The seven projects are coordinated collectively by the Muon Campus Coordinator who, incidentally, is also Level-2 Accelerator lead for Muon g-2. The basis for communication of schedule impacts between the Muon g-2 Project and these supporting activities (including the co-existant mu-2-e Project) has been devised using 18 high-level interface milestones.**

  - **Each of the projects has a Program Plan that describes the scope of work and in addition each of the four AIP projects has a requirements document that outlines the high-level target-goals. The requirements documents under 'change-control' and were formalized one or two years ago. Any further changes would require a re-evaluation and re-approval cycle.**

- **Off-Project Work - Comments:**

  - **The 18 interface milestones typically show completion of a given project and are not defined in sufficient detail to flag specific issues with their completion. Since most (if not all) supporting projects are centrally-managed this may be adequate.**

  - **The requirements documents were signed off before the performance of the storage ring (with design modifications) was fully developed. As such these are effectively specifications that state succinctly what the upstream systems are expected to be able to do.**

  - **Intra-project level-2 interfaces are described in the top-level project document.**

- **Resources - Finding:**
  - **Within the accelerator enclosure and the storage ring building experienced Installation and Integration Managers (2) are in place and a daily work-management process has been realized. The scope of work, especially in the accelerator enclosure, is already quite large and is scheduled to increase substantially. Work in a particular area may span several different projects; Muon g-2 and AIP. Lessons-learned from Accelerator and Neutrino beamline Upgrades (ANU) guide traveler implementation and inventory management and these lessons have been effectively applied across multiple-projects.**

- **Resources - Comment:**
  - **Proper management of skilled-labor resources (electrical and mechanical technicians) is quite important as these resources are likely to limit progress in 2016 and 2017. Technical support needs of power supply and instrumentation work appears to be quite heavy.**

- **Ring Magnet - Finding:**
  - **A major milestone is planned for mid-FY2015 when the storage ring superconducting magnet will be cooled-down and powered for the first time since arriving at Fermilab, indeed for the first time in many years. A broad-range of activities including safety sign-off, magnet assembly, cryogenic system interconnection and power supply testing are foreseen in the next 7 months.**

- **Ring Magnet - Comment:**
  - **Cool-down and excitation of the storage ring superconducting magnet is a major step. The interface with the Cryogenics AIP appears to be in very good shape. Work on the magnet and supporting utilities is scheduled to increase substantially and could become difficult to manage. It is important to identify the cool-down critical-path and properly prioritize magnet work. A comprehensive QC/QA plan is necessary as the magnet will be a significant part of Fermilab experimental physics infrastructure for years to come. This plan needs to be developed.**

- **Ring Magnet - Recommendation:**
  - **Develop a comprehensive QC/QA plan for magnet cool-down and excitation.**

## 2.3 Technical Integration

M. Ross, SLAC*, B. Strauss, DOE/SC
C. Rode, TJNAF / SC-3



- **<u>Injection - </u>Comment:**
  - **Recent design work on beam optics, injection kicker, storage ring quadrupoles, and inflector magnets shows potential for significant improvements and requires formal review. An examination of upstream systems performance specifications must be included in these reviews and the AIP requirements may be revised if appropriate.**

- **<u>Injection - </u>Recommendation:**
  - **Implement a Formal External Review of storage ring injection and associated hardware.**

# 2.4 Instrumentation

R.Kass (OSU), W.Toki(CSU), W.Wisniewski(SLAC)*, R.-Y. Zhu(Caltech)
Subcommittee 4

1. Do the proposed technical design and associated implementation approach satisfy the performance requirements? How has the project team ensured that the subsystems will be fully integrated? Are the CD-4 goals reasonable and well defined? *Yes.*

3. Is the management structure and resources adequate to deliver the proposed technical scope within the baseline budget and schedule as specified in the PEP? *Yes.*

4. Is the documentation required by DOE Order 413.3B for CD-2 complete? *The Technical Design Report has been prepared.*

6. Has the project responded satisfactorily to the recommendations from the previous independent project review? *There were no recommendations from the last review.*

7. Is the detailed design sufficiently mature so that the project can commence procurement and fabrication? Are the current project cost and schedule projections consistent with the baseline cost and schedule in the PEP? Is the contingency adequate for risks? *Yes.*

8. Is the documentation required by DOE Order 413.3B for CD-3 complete? *The Technical Design Report has been prepared.*

# 2.4 Instrumentation

R.Kass (OSU), W.Toki(CSU),
W.Wisniewski(SLAC)*, R.-Y. Zhu(Caltech)
Subcommittee 4



- **Findings (1)**
  - Detailed management schedules and projections were provided.
  - The Detector group includes 97 collaborators in 24 institutions.
  - The tracker funding is $1,506K with $890K from an early career grant (with 38% uncertainty) and $604K in kind support from UK and Italy in labor costs. To date $100K has been spent.
  - For management: EVMS, monthly reports, 18 interface documents, critical paths and L2 milestones were shown. The module 0 construction is scheduled to start FY14 Q4. The first L2 tracker milestone is 1st tracker station is ready to install in two years in FY16 Q3.
  - The tracker group presented first non-magnetic test beam results with a 32 channel prototype which achieved a resolution of 270 microns at 1500 volts. The performance of this straw tracker design was said to be adequate for the g-2 physics goals. After the first test beam run, the design of the straw spacing has been changed from 5.5 to 6mm and the feed throughs are being redesigned.
  - Detailed test beams results (e.g. efficiencies vs voltage) were not presented. The straw detector spatial resolutions dependence on magnetic fields is not yet known.
  - A second test beam run is scheduled for January 2015. This results of this revised prototype and beam test will likely affect the final tracker design. A technical review of the results is scheduled to follow this beam test.

# 2.4 Instrumentation

R.Kass (OSU), W.Toki(CSU), W.Wisniewski(SLAC)*, R.-Y. Zhu(Caltech)

Subcommittee 4

- **Findings (2)**
  - The tracker manifold layout has HV resistors and HV blocking capacitors inside the gas manifold in the vacuum pipe. The front end electronics are also located there.
  - The Quality Control items were listed as leak rate, straw and wire positions, gain, S/N, alignment, metrology, gas purity, leak rate, and straw creep. Details were not presented. Liverpool has taken on the continuation of development of the QC protocols/system which will be used on both at Liverpool during construction and at Fermilab on delivery.
  - If a tracker station has a serious failure, a spare module(1 of three types) would replace the failed module. This was estimated that the ring could resume operation in two shifts. At this time there is no estimate of the probability of a module failing.
  - The Liverpool group has taken the lead in the assembly of the straws into the manifolds. This group is also designing and machining the mechanical alignment tooling necessary for the construction of the tracker modules.
  - The cooling of the straw detector was said to be inadequate in the Director's review and no solutions were presented in this DOE CD-2/3 review.
  - The previous Director's review comments that gas leaks from the straw tubes requires the use of vacuum pumps. The impact on the operation of the ring and the data quality with varying amounts of leakage was not presented in this DOE CD-2/3 review.
  - The gas system necessary for the tracker system was briefly discussed.
  - The high voltage system necessary for the tracker system was briefly discussed.
  - A scheme for measuring the tension of the wire in straw was discussed.

# 2.4 Instrumentation

R.Kass (OSU), W.Toki(CSU), W.Wisniewski(SLAC)*, R.-Y. Zhu(Caltech)
Subcommittee 4

- **Findings (3)**
  - The calorimeter group proposed a PbF_2 crystal based total absorption calorimeter with large area (1.2 x 1.2 cm) SiPM readout. Recent beam test of a prototype matrix at SLAC test beam facility shows an energy resolution better than required.
  - The SLAC beam test also shows the SiPM bias power supply and a laser diode based monitoring system works as expected. While several detailed detector design choices, such as the crystal wrapping, the coupling between crystals and SiPMs and the final choice of laser diode etc., are yet to be made a working detector design exists as demonstrated by the beam test.
  - The calorimeter group chose two critical vendors: SICCA for PbF_2 crystals and Hamamatsu for SiPMs.
  - The proposed Calorimeter schedule and cost appear reasonable. Because of its relatively small scale as compared to other crystal calorimeters in the field no significant schedule and cost risk is foreseen.
  - The INFN group has contributed to the laser diode based monitoring system which is crucial for the success of the physics program.
  - While the cost of the calorimeter is covered by a MRI award from NSF, it is managed as a fully integrated part of the g-2 project.

# 2.4 Instrumentation

R.Kass (OSU), W.Toki(CSU), W.Wisniewski(SLAC)*, R.-Y. Zhu(Caltech)
Subcommittee 4

- **Comments (1)**

  - The Detector Team is to be commended for the progress made since the CD-1 Review.
  - The design is sufficiently complete to allow procurement of many longer lead time items.
  - The Committee believes the schedule shown by the Detector group is achievable. Resources are basically already in hand, and some major long lead-time components have already been ordered or will be ordered in the near future.
  - Detector is well managed. Adoption of a single CAM to manage the effort is the right step.
  - The L2 and L3 managers are doing well with the cost and schedule tools. BOEs exist and are well developed.
  - R&D has focused on meeting physics requirements. It is important to develop additional headroom (ie, go beyond requirements), whenever possible, in case difficulties are encountered in full system implementations.
  - Several beam tests have been performed. Results of these tests have been used to select among detector options and to make design improvements. (The beam tests have also provided important team building opportunities.)
  - The Detector is close to the challenging transition from R&D to construction.

- **Comments (2)**

  - Selection of aluminized mylar straw technology was an excellent choice for the g-2 Tracker.
  - The particle rates in the hottest straws nearest to the beam with the inflector upgrade should be simulated and estimated so that the total charge per cm on the anode wire should be estimated to predict the lifetime of the straw.
  - Details of the QC measurements that will be performed on production detectors should be fully developed before the next independent project review.
  - The straw position or closest distance of approach resolutions should be estimated for all the straws which have different magnetic field values and directions. If possible an actual measurement of the time-distance relation should be made.
  - The close proximity of the capacitors inside the gas manifold may lead to crosstalk between adjacent straws.
  - Design for removal of electronics generated heat from the tracker stations located in vacuum needs to be completed. This may require a finite element thermal analysis.
  - The addition of the large group from Liverpool to the Tracker team, which provides a substantial expansion of the effort available for this system in construction and development of QA plans, is most welcome.

- **Comments (3)**
  - The upcoming Tracker beam test in January will be critical to finalizing the design of these devices. Participation of all Tracker stakeholders in both data taking and data analysis is important. The Tracker review that will follow completion of the test beam data taking should be scheduled only when the data analysis is mature. The full suite of performance parameters to be developed for the review should include resolution and efficiency as a function of position in the tube, including as a function of voltage. An acceptable leak rate should be demonstrated. Cross talk measurement results, performance of the in vacuum cooling system, and an update on the QA suite, should be presented. Details of the design should also be presented including design choices made.
  - The Calorimeter's test beam campaign appears to be very successful. Promising results from the very recent test beam at SLAC were presented. Unfortunately the timing of the test beam with respect to this review did not allow full analysis of the results. However, the Committee notes that the achieved energy resolution is consistent with the A4 $PbF_2$ calorimeter with PMT readout. The test beam results thus validate the proposed calorimeter detector concept. The technology choice of silicon photomultipliers (SiPMs) is excellent.
  - The energy resolution measured in the recent test beam is significantly better than the required resolution.

- **Comments (4)**
  - The vendor secured for the production of the crystals has a good track record for delivery. The production schedule is not aggressive. The preferred vendor for the SiPMs also has an excellent track record. It is expected that sole-sourcing with these vendors does not present significant risk.
  - Good progress has been made on the design and prototyping for the SiPM carrier electronics board that is to be mounted at the back of the crystal. How to mount this readout device on the crystal is a focus of design effort. The choice is air-gap or optical 'grease'. Design optimization is needed: it is easier to engineer an air-gap solution that can be reliably reproduced.
  - The crystal QA system was described as a turn-key operation. Measurements of transmission are done at three points on two orthogonal faces along the length of the crystal. It is essential that a measurement through the full length of the crystal be made.
  - Crystal and SiPM characteristics should be measured for the full complement of each of these devices. The team should reevaluate the adequacy of manpower at UW for the execution of both of these tasks.
  - The laser system has worked well in the test beam. The design and prototyping of this system has been carried out by the INFN supported Italian team. Final design needs completion. The proposed goal of 0.1% for the uncertainty in the knowledge of the gain is challenging but achievable.

# 2.4 Instrumentation

R.Kass (OSU), W.Toki(CSU), W.Wisniewski(SLAC)*, R.-Y. Zhu(Caltech)
Subcommittee 4



- **Comments (5)**
  - The committee welcomes the addition of the strong Italian group to cover the Calorimeter calibration effort.
  - Commendable progress has been made in backend electronics R&D, culminating in production of a waveform digitizer board that satisfies the 800 MSPS requirement.
  - DAQ is also progressing well.
  - The Slow Control provides overall integration of controls efforts. Slow controls are developed by each of the subsystems internally, matching the specific needs of each of the detector components. This solution is a good choice and allows the best use of effort. The MIDAS package has been chosen by the experiment. The selection was made considering the experience of the team. Unfortunately, Fermilab does not currently support this PSI developed and supported package. Fermilab is encouraged to reconsider providing local support for this package.

# 2.4 Instrumentation

R.Kass (OSU), W.Toki(CSU), W.Wisniewski(SLAC)*, R.-Y. Zhu(Caltech)
Subcommittee 4

- **Recommendations**
  1. Conduct a review of Tracker performance following the January beam test. Allow sufficient time before the review to completely analyze the data. Present results on the full suite of performance parameters. Include external experts as part of the review team.
  2. Fully characterize all of the crystals and SiPMs that are used in the calorimeter.

# 4. Cost and Schedule

R. Lutha, J. Kao, DOE SC-ISC

Subcommittee 5



1. Do the proposed technical design and associated implementation approach satisfy the performance requirements? How has the project team ensured that the subsystems will be fully integrated? Are the CD-4 goals reasonable and well defined?

2. Is the cost estimate and schedule consistent with the plan to deliver the technical scope? **Yes** Is the contingency adequate for the risk? **Yes, except for the potential negative results of a ring cold test.**

3. Is the management structure and resources adequate to deliver the proposed technical scope within the baseline budget and schedule as specified in the PEP? **Yes the project staff is highly matrixed and will have to be coordinated with the rest of the Laboratory efforts**.

4. Is the documentation required by DOE Order 413.3B for CD-2 complete? **Yes**

6. Has the project responded satisfactorily to the recommendations from the previous independent project review? **Yes**

7. Is the detailed design sufficiently mature so that the project can commence procurement and fabrication? Are the current project cost and schedule projections consistent with the baseline cost and schedule in the PEP? **Yes** Is the contingency adequate for risks? **Yes, except for the potential negative results of a ring cold test.**

8. Is the documentation required by DOE Order 413.3B for CD-3 complete? **Yes, need to state the final design report.**

## FINDINGS

- Total Project Cost (TPC) of $46.4 million, with NSF ($3.6M, Early Career Grant ($2.5), and International contributions (Detectors) not included in the TPC.
- Contingency of $10.1M (39% BAC to go) consisting of $7.1M in estimate uncertainty and $3M in risks.
- Up to $100K in contingency can be used by the project before approval by the FPD is needed.
- A project change request for $400k in contingency is in progress  due to new overhead rates.  The overhead rate risk is currently in the risk register.
- Project is managing to the early completion of the 3rd  QTR 2017 with a CD-4 date of the 3rd QTR 2019  (approximately 2 years of schedule contingency).
- A schedule risk analysis was completed and the schedule contingency is considered adequate.

## FINDINGS continued

- Project Baseline basis of estimate (BOE) consists of (30% Actual, 2% Purchase Order, 15% Project Management, 39% Engineering Estimate, 9% Vendor Quote, 5% Expert Opinion).
- The two off project items that impact the project ability to achieve the KPPs
  - Cryo Ready to Cool g-2 (AIP) (3/15/15)
  - Beamline Enclosure Beneficial Occupancy (GPP) (6/9/15)
- The critical path currently runs through completing the accelerator components. If the accelerator schedule is advanced by 4 months, the storage ring assembly, and installation of the injection subsystems/detector would all become part of the critical path.
- Through June 2014, the project is 31% complete
- The risk register was updated in July 2014 and contains both a bottoms up and top down analysis.

## FINDINGS continued

- EVMS is in place and the project has been "practicing" performance measurement since May 31st.
- The constraints in the P6 schedule have been reduced from 548 to 49 since the June 2014 Director's review.
- Project continues to progress in these areas:
  - CAM training on EVMS
  - Monthly feedback report to CAMs
  - Implementing a weekly warning report for CAMs
- In kind contributions of project scope (detector) are being treated, monitored and managed as being part of the project.

## COMMENTS

- The CAM interviews demonstrated ownership and confidence in their scope, cost and schedule estimates. They discussed schedule float, work on the critical path, and their risks. The CAMs are regularly trained and understand EVMS processes.
- There are a significant number of external dependencies, and the project is actively monitoring these by using milestones on the schedule.
- Continue to develop project monitoring tools such as the monthly CAM turnaround report.
- Consider using eCAM notebook as a tool for CAMs to identify forward looking issues and for monthly CAM reports.
- Project risks are identified and being actively managed.
- Risk for potential failed ring cold testing is not fully accounted for in project contingency.

## COMMENTS continued

- Schedule contingency appears adequate.
- Project Cost and Schedule are well defined and appear reasonable.
- Continue to clean up the schedule constraints in the project schedule
- Need to implement a formal monthly report
- Prior review comments have been adequately addressed

**RECOMMENDATIONS**

- None

## Muon g-2 PROJECT STATUS
## As of June 2014 (Pre CD-2)

| | | |
|---|---|---|
| Project Type | MIE | |
| CD-1 | Planned: | Actual: 12/19/2013 |
| CD-2 | Planned: 4QFY14 | Actual: |
| CD-3 | Planned: 4QFY14 | Actual: |
| CD-4 | Planned: 3QFY19 | Actual: |
| TPC Percent Complete | Planned: ______% | Actual: approx. 31% |
| TPC Cost to Date | $11.2M | |
| TPC Committed to Date | $11.8M | |
| TPC | $46.4M | |
| TEC | $31.5M | |
| Contingency Cost (w/Mgmt Reserve) | $10.07 | ______38.6% to go |
| Contingency Schedule on CD-4b | approx. 24_months | ___68_% |
| CPI Cumulative | N/A | |
| SPI Cumulative | N/A | |

## 3. Environment, Safety and Health

Steven Trotter, ORNL / SC6

3. Is the management structure and resources adequate to deliver the proposed technical scope within the baseline budget and schedule as specified in the PEP? Yes.

4. Is the documentation required by DOE Order 413.3B for CD-2 complete? Yes.

5. Are environment, safety and health (ES&H) aspects being properly addressed? Yes.

6. Has the project responded satisfactorily to the recommendations from the previous independent project review? Yes.

7. Is the detailed design sufficiently mature so that the project can commence procurement and fabrication? Are the current project cost and schedule projections consistent with the baseline cost and schedule in the PEP? Is the contingency adequate for the risks? Yes.

8. Is the documentation required by DOE Order 413.3B for CD-3 complete? Yes.

7. Is the detailed design sufficiently mature so that the project can commence procurement and fabrication? Are the current project cost and schedule projections consistent with the baseline cost and schedule in the PEP? Is the contingency adequate for the risks? Yes.

8. Is the documentation required by DOE Order 413.3B for CD-3 complete? Yes.

# 3. Environment, Safety and Health

Steven Trotter, ORNL / SC6

- Findings
  - ESH programs for the project are mature and implemented throughout all levels of the project.
  - Furthermore, the project has responded appropriately to recommendations from prior DOE/SC review(s).
  - ISM principles are employed in planning and execution of work throughout all levels of the project.
  - For August 1, 2013 – July 20, 2014, 33,438.40 hours worked on project. TRC 0.00; DART 0.00 (contrast Fermilab rates TRC 1.06; DART 0.40).
  - On July 22, 2014, an employee twisted ankle at work, currently being evaluated.
  - One near miss associated with hoisting and rigging was identified, investigated, and appropriate lessons learned were developed and distributed.

- Findings (continued)
  - The project has prepared and updated a Hazard Analysis Report. The Hazard Analysis Report for the Muon g-2 Project v2.4 was approved on July 3, 2014
  - The project has prepared and implemented an Integrated Safety Management Plan. The Integrated Safety Management (ISM) Program of the Muon g-2 Project v2.1 was approved on July 3, 2014.
  - The project has further developed and updated and the Quality Assurance Program. The Quality Assurance Program for the Muon g-2 Project was issued on June 26, 2014 and is currently awaiting final approval by the Project Manager.
  - NEPA Categorical Exclusion was approved on December 20,2012.

# 3. Environment, Safety and Health

Steven Trotter, ORNL / SC6

- Comments

- Although the Accelerator Safety Program is independent of the project, consideration should be given to reporting on progress and implementation of the program with respect to the project forthcoming DOE reviews.

- The NEPA documentation mentions that airborne radionuclides will be generated by Muon g-2 beam operations and released to the environment. Per discussions with Fermilab ESH staff, the respective emissions are a minor source and therefore the source is exempt from permitting. For example, the highest dose equivalent to any member of the public was estimated to be 0.0053 mrem, well below the US EPA standard of 10 mrem/year and much less than the EPA's continuous monitoring threshold of 0.1 mrem/year.

# 3. Environment, Safety and Health

Steven Trotter, ORNL / SC6



- Recommendations
  - None.

**Do the proposed technical design and associated implementation approach satisfy the performance requirements? How has the project team ensured that the subsystems will be fully integrated? Integration coordinator, integration meetings and integration milestones. Are the CD-4 goals reasonable and well defined? Yes**

**Is the management structure and resources adequate to deliver the proposed technical scope within the baseline budget and schedule as specified in the PEP? Yes, with comments noted.**

**Is the documentation required by DOE Order 413.3B for CD-2 complete? Yes, but need to put requirements document under configuration control when finalized**

**Has the project responded satisfactorily to the recommendations from the previous independent project review? Yes**

**Is the detailed design sufficiently mature so that the project can commence procurement and fabrication? Are the current project cost and schedule projections consistent with the baseline cost and schedule in the PEP? Yes Is the contingency adequate for risks? Yes**

**Is the documentation required by DOE Order 413.3B for CD-3 complete? Yes**

## Findings

- A Physics requirements document was shown to the Committee.

- Those requirements flow down to the TDR describing the baseline Project technical scope.

- Resources; The g-2 L3 managers expressed their major concern to be manpower availability. However, the Project has had very good experience so far.

- Interface Miestones (ML) between the Project and AIP/GPP are in place and being tracked.

## Findings – II

- Operations begins in March, 2015

- Preliminary discussions on operations indicate a steady state support level of 5 M$/yr.

- The Project depends on the success of the AIP and GPP efforts. They are the critical path for the g-2 Project.

- There are approximately 5 M$ in deliverables outside the scope of the Project, largely in the Detectors L2.

- The Project is, however, responsible for installation of detectors.

- Detector installation is typically connected to the ring itself, for example tracking in the vacuum.

## Comments

- **CD2 baselining - A strong PM team is in place and functions well.**

- **The WBS and BOE capture the Project scope with sufficient granularity and specificity. Drilldowns were done successfully.**

- **The requirements document should be under configuration control and the Change Control Board should be in place prior to CD-2.**

- **New people for DPM and for EQH&Q Coordinator need to be found with a generous time of overlap to ensure a smooth transition.**

- **In future a labwide manpower plan would be a useful tool to assure all stakeholders that sufficient resources are availlable in a timely manner since 3 FNAL Divisions are involved.**

- **For KPP adding testing to the "threshold" level could be useful. Thresholds could be strengthened for most deliverables.**

## Comments – II

- Scope contingency – positive and negative should be identified prior to CD-2.

- Reduced scope is now limited only to reduced installation. Project items should be considered.

- A useful augmentation of the interface ML would be the creation of a series of “Interface Control Documents”, used in other projects, which specify the interface between Project L2 to each other L2 or to AIP/GPP, flowing down from the requirements document and also under configuration control. The ICD bring the physics down to the appropriate level.

- Prior to the start of operations a Transition to Operations Plan between FNAL and the g-2 experiment covering operations should be in place.

## Comments – III

- The Project should continue to develop mechanisms between the Project and FNAL to assure that the associated AIP and GPP projects meet the requirements and schedules of the g-2 Project.

- g-2 should not bear the risks of the AIP and GPP work.

- Consider tightening the reporting between Detector and the other L2 efforts of the project since much of the funding is off Project in the case of detectors.

- There is an opportunity with an improved inflector to increase the g-2 luminosity by factors > 2, yielding more and more timely Physics which should be fully explored.

- There is about 1 M$ carryover into FY15.

## Recommendations

- **Within the Project, construct and track under change control interface control documents flowing from the requirements and of sufficient granularity to cover the interdependences of the L2 efforts and the interdependences with the AIP/GPP projects.**

- **Continue to work on improved inflector design until a decision can be made. To that end, formulate a schedule and plan whereby an inflector decision can be revisited on the basis of cost experience in a timely fashion.**

- **The Project and the laboratory should make every effort to accomplish a timely cold test of the ring.**

**Add a L1 Milestone (ML) for "All detectors ready to install" to cover items provided by other than DOE g-2 Project funds.**

**Make an agreement with FNAL that the Project is not liable for AIP/GPP risks prior to CD-2.**